CHAPTER 3.5
GEOMEMBRANE

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3.5-1. GENERAL. Geomembranes are thin sheets of flexible, relatively impervious, plastic materials whose primary function is to act as a barrier to liquids and vapors. The plastic materials are manufactured into sheets and transported to the job site where placement and field seaming are performed. The most common types of geomembranes currently being used for landfill covers are polyvinyl chloride (PVC) and various forms of very flexible polyethylene (VFPE). A minimum thickness of 1.0 mm (40 mils) is often specified for cover geomembranes due to constructibility concerns. High density polyethylene (HDPE) is generally not used for landfill covers when a large amount of differential settlement is anticipated because it is less flexible than PVC or VFPE which makes it more susceptible to damage by differential settlement. HDPE does have very good resistance to chemical attack, therefore, it is commonly used for liner systems where less differential settlement is expected and resistance to chemical attack is important. A minimum thickness of 1.5 mm (60 mils) is often specified for liner geomembranes. Geomembranes can be manufactured with textured surfaces which improve their interface frictional resistance. Textured geomembranes are generally not used unless the slopes of the cover or liner are equal to or steeper than 1V on 4H. In general, textured geomembranes are more expensive, have diminished physical properties, have more manufacturing defects, and are more difficult to field seam and inspect than non-textured geomembranes.

a. Preconstruction Submittals. The contractor should provide preconstruction submittals as required by the specifications. The following is a list of typical submittal requirements.

(1) Manufacturer's QC manual and QC test results.

(2) Installers QC manual. Verify the installer has been approved by the manufacturer.

(3) Geomembrane panel layout and penetration detail drawings. For landfill liners, the panel layout should be arranged so that the number of seams in the sump bottom are minimized or eliminated.

(4) Manufacturer's, fabricator's, installer's, inspector's, and QA laboratory's qualification statements including resumes of key personnel involved in the project.

(5) Interface friction test results.

(6) Sample of geomembrane (if required).

b. Construction Submittals. The contractor should provide construction submittals as required by the specifications. The following is a list of typical submittal requirements.

(1) Final as-built drawings of the geomembrane installation showing sheet numbers and seam numbers. The locations of repairs, destructive seam samples, and penetrations should also be shown.

(2) Field test results for geomembrane thickness.

(3) Field seam test results for leaks, shear strength, and peel strength.

(4) QA test results for shear and peel strength.

(5) Seam samples for permanent record (if required).

c. Delivery, Storage, and Handling.

(1) A QA Representative should be present during delivery and unloading of the geomembrane to inspect for damage.

(2) Verify that rolls are labeled with the manufacturer's name, product identification, lot number, roll number, roll dimensions, and date manufactured.

(3) The QA Representative should record roll numbers, date delivered, name of manufacturer, and product type. This data is used to verify manufacturer's QC data sheets have been submitted for the rolls being delivered.

(4) Geomembrane rolls should be handled and unloaded with load carrying straps, a fork lift with a stinger bar, or an axial bar assembly should be used.

(5) Do not allow rolls to be dragged, lifted by one end, or dropped to the ground.

(6) The geomembrane should be protected from puncture, abrasion, excessive heat and cold, or other damaging conditions during storage.

(7) Temporary storage should be in a flat dry area where standing water cannot accumulate. Verify the ground surface contains no stones or other sharp objects.

(8) Ensure that rolls of geomembrane are not stacked more than 5 high.

(9) Do not allow pallets of accordion folded geomembrane (PVC) to be stacked on top of each other.

d. Weather Limitations.

(1) Geomembrane should be deployed and field-seamed only when the geomembrane is dry.

(2) Check manufactures recommendations for allowable temperatures for deployment and seaming.

(a) On hot days, watch the geomembranes as they are unrolled or unfolded to see if they stick together to the extent where tearing or straining of the geomembrane occurs. The upper limit for sheet temperature is very specific to the type of geomembrane. Geomembrane should not be deployed if this temperature is exceeded unless it can be shown that the geomembrane is not being damaged.

(b) A sheet temperature of 0 degrees C (32 degrees F) is typically the lower limit at which geomembrane should be unrolled or unfolded unless it is shown that the geomembrane can be deployed without being damaged.

(3) In marginal weather conditions, require the contractor to make test seams to confirm that satisfactory seams can be constructed.

3.5-2. PRODUCTS.

Geomembrane.

(1) Cross check the roll numbers of the geomembrane delivered to the site against the roll numbers on the manufacturer's QC test data to ensure they match. Ensure the geomembrane meets the property requirements outlined in the specifications for material type and physical properties.

(2) Polyethylene seaming rods and pellets should be manufactured of resin which is essentially identical to that used in the geomembrane.

(3) For textured geomembranes, visually inspect the texturing as the rolls are being deployed. Make sure the texturing is uniform over the entire roll.

3.5-3. EXECUTION.

a. Subgrade Preparation

(1) The condition of the subgrade should be checked by the QA Representative and installer each day that geomembrane is placed. The condition of the subgrade is generally certified in writing by the QA Representative and installer each day prior to geomembrane placement.

(2) Verify the final lines and grades of the subgrade are correct prior to geomembrane placement.

(3) Ensure that surfaces to be lined with geomembrane provide a firm, unyielding foundation with no sharp breaks in grade.

(4) Soil subgrade should be rolled with a smooth drum compactor of sufficient weight to remove any protrusions, wheel ruts, foot prints, or other abrupt changes in grade.

(5) Inspect for rocks larger than specified requirements (typically 12.5 mm (1/2 inch) in diameter) or any other debris which could damage the geomembrane. This material should be removed from the upper lift of soil layers to be covered with geomembrane.

(6) Verify that construction equipment used to deploy geomembrane does not deform or rut the subgrade. Typically, ruts should not be greater than 25 mm (1.0 in.) in depth.

b. Geomembrane Deployment.

(1) A QA Representative should be present at all times during geomembrane installation.

(2) To avoid confusion, the installer and QA Representatives should use different colored markers that are easily visible on the geomembrane. The markers should be semi-permanent and compatible with the geomembrane.

(3) Look for damaged geomembrane during installation. Damage may include things such as permanent creases, folds, crimps, gouges, holes, scratches, and inadequate texturing. Any area requiring

repair should be clearly marked.

(4) Carefully inspect deployed geomembrane for damage if it has been displaced by wind.

(5) Do not allow personnel working on the geomembrane to smoke or wear shoes which could damage the geomembrane.

(6) Only geomembrane that can be anchored and seamed together the same day should be deployed.

(7) Ensure geomembrane panels which have been deployed are secured with acceptable ballast to prevent uplift by wind.

(8) Sand bags are typically used for ballast. A continuous line of sand bags should be placed along all exposed edges of geomembrane.

(9) Seams should be oriented parallel to the line of maximum slope.

(10) Where seams can only be oriented across the slope, verify the upper sheet is lapped over the lower sheet.

(11) If a composite liner (geomembrane/clay) is being constructed, make sure the geomembrane is placed directly on the underlying clay layer. Other geosynthetics should not be placed between the geomembrane and the clay layer. Slip sheets are sometimes used to position textured geomembranes. Verify the slip sheets are removed after the geomembrane has been correctly positioned.

(12) There should be sufficient slack in the deployed geomembrane to prevent tensile stresses from occurring when the temperature drops, causing the geomembrane to shrink.

(13) The trampoline effect occurs when a membrane shrinks and pulls away from the subgrade at corners. Inspect for the trampoline effect in the morning when temperatures are lowest. The trampoline effect often occurs along the bottom edge of liner systems.

(14) Ensure that the geomembrane does not have excessive slack to the point where folds in the geomembrane lay over during placement and covering.

(15) Inspect the surface of the deployed membrane in the morning for evidence of protrusions in the subgrade. Subgrade protrusions are more easily identified in the morning because the membrane has contracted due to the cooler night time temperatures.

(16) Verify that each deployed geomembrane panel is given a panel number which is recorded on the daily reports and as-built drawings.

c. Spotting.

When a geomembrane roll or panel is deployed it is generally required that some shifting will be necessary before field seaming begins. This is called spotting by many installers.

(1) Spotting of deployed geomembranes should be done without disturbing the subgrade soil or geosynthetic materials.

(2) Temporary tack welding (usually with a hand held hot air gun) of all types of thermoplastic geomembranes should be allowed at the installers discretion.

(3) When temporary tack welds are used, verify the welds do not interfere with the primary seaming method, or with the ability to perform subsequent destructive seam tests. Tack welds should not be strong enough to produce a film tearing bond.

d. Seams. Geomembrane seams fall into four general categories which are described below. This document will focus on extrusion and thermal fusion seams since they are the most common seam types used on projects the Corps of Engineers has been involved with. Additional information on the fabrication of geomembrane field seams can be found in EPA/530/SW-91/051.

- Extrusion Welding Seams. A ribbon of molten polymer is extruded over the edge of, or in between, the two surfaces to be joined. The molten extrudate causes the surfaces of the sheets to become hot and melt, after which the entire mass cools and bonds together. This type of seam is used for polyethylene geomembranes.

- Thermal Fusion. The surfaces of geomembranes are melted using an electrically heated resistance element in the shape of a wedge that travels between the two sheets to be seamed. The geomembranes are then pressed together using a set of rollers. A double wedge weld is usually used. A double wedge weld is created with a split wedge which forms two parallel seams with a uniform unbonded space between them. This space can be used to evaluate seam quality and continuity by pressurizing the unbonded space with air and monitoring for drops in pressure. This type of seam can be used for polyethylene, chlorosulfonated polyethylene, or PVC geomembranes.

- Chemical Fusion. Chemical fusion seams make use of a liquid chemical applied between the two geomembrane sheets to be joined. After a few seconds (required to soften the geomembrane surfaces) pressure is applied to make complete contact and bond the sheets together. Bodied chemical fusion seams are similar to chemical fusion seams except that geomembrane resin is added to the adhesive to increase the viscosity of the liquid for use on slopes or to adjust the evaporation rate of the chemical. This type of seam can be used for PVC or CSPE geomembranes.

- Adhesive seaming. Adhesives are applied to both geomembrane surfaces. After reaching the proper degree of tackiness, the two geomembrane sheets are placed on top of one another, followed by application of roller pressure. This type of seam can be used for PVC or CSPE geomembranes.

e. Trial Seams.

(1) Trial seams should be made on test strips of excess geomembrane under field conditions to verify that seaming methods are adequate. Make sure trial seams are constructed in the same weather conditions as the actual field seams.

(2) Require trial seams to be made each day prior to production seaming, whenever there is a change in seaming personnel or seaming

equipment, and at least once every four to five hours.

(3) Require additional trial seams if there is a quick change in weather conditions (temperature and/or sunlight) which causes a significant change in the temperature of the geomembrane.

(4) A QC sample should be obtained from each trial seam with the seam centered lengthwise. For some projects, a QA sample and an archive sample may also be collected from the trial seam. Ensure each trial seam sample is adequately labeled with the sample number, date, who will test the sample, ambient temperature, and any other information required by the QA plan or specifications.

(5) Typically, 6 to 10, 2.54 cm (1 inch) wide specimens (coupons) are cut from the sample for testing by the geomembrane installer. Half of the seam specimens will be tested for shear strength and half for peel adhesion using an approved tensiometer with a digital readout.

(6) Ensure field tensiometers used have an up to date calibration certificate.

(7) Require a second trial seam be made if tests from the initial trial seam fail.

(8) If the additional trial seam fails, the seaming apparatus or seamer should not be used until the deficiencies are corrected and two consecutive successful trial seams are made.

(9) While the test seams are being tested, the seaming crew may continue to work as long as the seams they make since their last acceptable test sample strip was prepared are completely traceable and identifiable.

(10) The QA Representative should ensure the following information is recorded for each trial seam: sample number, date, test results, welder number, ambient temperature, welder temperature and pressure, and rate of seaming. For chemical seams, the chemical type and mixture should be recorded.

f. Field Seams.

(1) General Requirements.

(a) The subgrade should be firm and dry prior to seaming. Due to wet subgrade conditions, the contractor may choose to place a sacrificial “rub sheet” under the seam to act as a barrier against moisture.

(b) Seam preparation is crucial to obtaining quality welds. Verify the areas to be seamed are clean and dry. Even morning dew can affect the quality of seams.

(c) Seaming should be performed when the ambient temperature is in the allowable range as described in the installer’s QC manual. The location where ambient temperature is measured needs to be agreed on prior to the start of installation. Often, the ambient temperature is defined as the temperature 150 mm (6 inches) above the geomembrane surface.

(d) All geomembranes which have been deployed should be seamed together by the end of the work day. Do not allow open seams to be

left overnight.

(e) Verify geomembrane sheets are overlapped the minimum specified distance (typically, 76 mm (3 inches)) prior to seaming.

(f) Verify that seams extend to the outside edge of the sheets.

(g) Excessive waves along seams during the seaming operation should be avoided. When this occurs, due to either the upper or lower sheet having more slack than the other or because of thermal expansion and contraction, it often leads to the formation of "fishmouths". Inspect for fishmouths in completed seams. Fishmouths should be trimmed, laid flat and reseamed.

(h) Pay special attention to the construction of seams in the sumps of liner systems. This is where liquids will accumulate in the liner, therefore, it is critical that these areas are constructed properly.

(i) Seaming of geomembranes to be placed in an anchor trench can be accomplished by temporarily supporting the adjacent sheets to be seamed on a wooden support platform. This allows continuous horizontal seams to be made out to the end of the geomembrane sheets. The wooden platform is removed after the seam is complete and the geomembrane is allowed to drop into the anchor trench.

(j) Destructive and nondestructive tests can also be performed while the seamed geomembranes are temporarily supported in the horizontal position.

(k) Ensure that protection is provided if a generator is placed on top of the geomembrane. Fuel for generators must be stored away from the geomembrane. If accidently spilled on the geomembrane, it must be immediately removed. Spill areas should be inspected for damage and repaired if necessary.

(l) Seams around pipes and other appurtances are the most difficult seams in a facility. Therefore, these seams should be carefully inspected to ensure they are leak free. Ensure pipes are long enough to allow pipe boots to be attached.

(m) The QA Representative should ensure the following information is recorded for each seam: seam number, date, seaming unit used, name of seamer, and any other information called for in the specifications or QA plan.

(2) Polyethylene Geomembrane Seams.

(a) Fusion seams. Polyethylene geomembranes should be seamed by thermal fusion methods (double hot wedge welds) wherever possible. Look for the following when observing fusion welds.

- The type of geomembrane, rate of seaming, and ambient factors such as clouds, wind, and hot sun require the temperature setting of the wedge to vary. Depending upon the records to be kept, one might record a number of different temperatures. For example, the temperature of the hot wedge, the temperature of the seaming area and the ambient temperature. This is a site specific decision usually determined by the specifications and the QA plan.

- At least two people are required in making hot wedge

welds: one operator and one helper.

- A leak-proof T-connection is necessary wherever intersecting seams are to be joined together. At such locations, the hot wedge device must be removed a short distance (approximately 150 mm (6 inches)) from the intersecting seam. For polyethylene geomembranes, this short distance must be completed by extrusion fillet seaming.

- A smooth insulating plate or heat insulating fabric should be placed beneath hot welding devices while they are not in use.

(b) Extrusion Seams. Extrusion welding should only be allowed for patching and seaming around appurtenances. Look for the following when observing the construction of extrusion welded seams.

- Heat tacking is often used to hold geomembranes in place so that extrusion seams can be made more easily. A hot air device is used to make tack welds.

- The surfaces of all polyethylene geomembranes should be ground prior to extrusion welding using an electric rotary grinder. Number 80 to 100 grit size is typically used for grinding. All of the surface sheen in the area to be seamed should be totally removed.

- Grinding marks should be oriented perpendicular to the seam direction and no marks should extend beyond the extrudate.

- In general, grinding marks should not appear beyond 6 mm (.25 inches) outside of where extrudate is placed.

- The depth of the grinding marks should be no greater than 10 percent of the sheet thickness.

- Verify all of the material that has been ground from the geomembrane is wiped or blown away from the actual seaming zone.

- Extrusion welding should begin within 10 minutes after grinding. The extrusion bead should be centered over the top of the geomembrane seam.

- For HDPE geomembranes which are 1.5 mm (60 mils) or greater in thickness, the leading edge of the upper sheet should be beveled. The upper geomembrane must be lifted off the lower so the lower sheet is not damaged by the grinder.

- Extrudate thickness should be approximately equal to or greater than the specified sheet thickness measured from the top of the upper sheet to the top or crown of the extrudate. Excessive squeeze-out of extrudate along the edges of the seam is acceptable as long as it is adequately joined to the geomembrane.

- Visual inspection of the extrudate bead should be made for straight line alignment, height, and uniformity of surface texture. There should be no bubbles or pock marks in the extrudate. Such surface details on the extrudate

indicates the presence of air, water or debris within the extrudate.

- Where extrusion welds are temporarily terminated long enough to cool, they should be ground prior to applying new extrudate over the existing seam.

- After temporary work stoppages, the extrusion welder should be purged of all old extrudate in the barrel. The extrudate should not be discharged onto the surface of previously placed geomembrane or the geomembrane subgrade.

- A smooth insulating plate or heat insulating fabric should be placed beneath hot welding devices while they are not in use.

(3) Non-Polyethylene Geomembrane Seams.

(a) Non-polyethylene geomembranes can be seamed by thermal fusion or chemical methods.

(b) Seaming adhesives, solvents, or chemical cleaning agents should not be stored on top of the geomembrane and only spill-resistant containers should be used while working with these materials on the geomembrane.

(c) For chemical fusion and adhesive fabricated seams, testing cannot be performed until adequate curing of the seam occurs. During this curing time, make sure all production seaming is tracked and documented.

(d) Accelerated oven curing of chemical and adhesive fabricated seams is acceptable to obtain test results as soon as possible.

g. Field Sampling and Testing.

(1) Non-Destructive Leak Testing.

(a) Verify and document that field seams are tested for leaks over their full length. The QA Representative should verify the following is being recorded: date, seam number, test unit number (if applicable), name of test person, test data, and outcome of testing.

(b) Pressure testing should be used to test double hot wedge weld seams. This is done using the following procedure.

- Isolate a section of seam. No limitations are generally placed on the length of seam that can be tested.

- Pressurize the isolated channel using a hollow needle connected to an air pump. Typically the pressure used is 167 to 267 kPa (25 to 40 psi).

- Monitor for pressure drops over a specified period of time (typically 5 minutes).

- If the pressure drop is less than a specified value, the seam passes. The allowable pressure drop depends on the initial pressure in the seam. A typical allowable pressure drop is 20 kPa (3 psi).

- Visual observation or listening for escaping air will often determine the location of leaks.

- After the test is complete, the end of the seam which is opposite of where the air pump is located should be cut. A QA Representative should be present when the seam is cut open. Listen for escaping air to ensure the seam is continuous over the full length tested.

(c) A vacuum box is often used for extrusion welds and other seams where it is not possible to pressure test. The vacuum test procedure typically consists of the following steps.

- Wet a section of seam with soapy water.
- Place the vacuum box over the seam and create a vacuum.
- View the seam through the transparent window in the box for approximately 10 seconds. If no bubbles are evident, then the area is considered passing.
- If bubbles are evident, mark the area for repair, perform the repair, and repeat the vacuum test.

(d) Verify seam testing is performed as the seaming work progresses, not at the completion of field seaming.

(e) Ensure the location, date, test number, name of test person and results are recorded for all seam leak tests.

(2) Destructive Field Seam Testing. Destructive testing of seams is conducted to provide a direct evaluation of seam strength and bonding efficiency. Destructive testing involves two types of tests: shear and peel tests.

(a) Typically, one destructive test sample should be taken per 230 meters (750 feet) of field seam. Observe all production seam sample cutting.

(b) Do not identify sample locations to the installer prior to seaming. Ask for additional seam tests if seams appear to be of questionable quality.

(c) Samples are typically a minimum of 300 mm (12 inches) wide by 1.1 m (42 inches) long with the seam centered lengthwise.

(d) Each sample is typically cut into three equal pieces with one piece retained by the installer, one piece given to the QA laboratory, and the remaining piece retained by the Government for possible testing and permanent record. Ensure that the samples going to the QA laboratory are properly labeled and packaged as described in the paragraph entitled “Trial Seams”.

(e) Ensure each sample is numbered and cross referenced to a field log and also shown on the record drawings. The reason for taking the sample should also be indicated, e.g., routine, suspicious feature, change in sheet temperature, etc.

(f) Shear and peel tests are typically performed by both the installer and the QA laboratory to ensure the seams have adequate strength. Reference the paragraph entitled "Trial Seams" for a description of the testing procedure to be used. The QA Representative should monitor and document all destructive seam tests performed by the geomembrane installer.

(g) Compare the results of the field tests to the QA laboratory test results to make sure they agree. Require additional testing if there is a disagreement between the sets of test data.

(h) The QA Representative should ensure the following information is recorded for each seam sample tested: sample number, date, test results, welder number, ambient temperature, welder temperature and pressure, and rate of seaming. For chemical seams, the chemical type and mixture should be recorded.

(i) Ensure destructive seam sample holes are repaired and nondestructively tested for leaks the same day they are cut.

h. Defects and Repairs.

(1) Destructive Seam Test Repairs.

(a) Seams that fail destructive seam testing may be cap stripped by seaming an additional strip of material over the failed seam between any two passed destructive test locations.

(b) Alternatively, the contractor may choose to try to isolate the weak area of the seam by retracing the seaming path to a location a specified distance (typically, at least 3.1 m (10 feet)) on either side of the failed seam location using the following procedure:

- At each location, samples should be taken so the contractor can perform additional shear strength and additional peel adhesion tests;
- If these tests pass, then the remaining seam sample should be sent to the QA laboratory for shear strength and peel adhesion tests;
- If these laboratory tests pass the specified strength criteria, then the seam should be cap stripped between passing destructive tests;
- After cap stripping, the entire cap stripped seam should be tested for leaks; and
- Documentation of all failed destructive seams should be recorded on the as-built drawings.

(2) Patches.

(a) Patching and cap stripping should be used to repair large holes, tears, and locations where destructive seam samples were taken. Ensure patches have rounded corners and extend a minimum of 15.3 cm (6 inches) beyond the edge of defects.

(b) Minor localized flaws such as pin holes can be repaired by spot welding.

(c) Ensure repairs are non-destructively tested for leaks.

(d) Verify all repairs are documented in the daily reports and recorded on the as-built drawings.

i. Penetrations and Connections.

(1) Factory fabricated boots should be used wherever possible.

Boots are prefabricated connections which allow a water-tight seal to be constructed at pipe penetrations.

(2) The skirt of the pipe boot which flares away from the pipe penetration should typically have at least 300 mm (12 inches) of geomembrane on all sides of the pipe.

(3) Verify non-destructive leak testing is performed on the seams which attach the skirt to the geomembrane.

(4) A stainless steel clamp is generally used to attach the boots to pipes. A cushion of compressible material should be placed between the clamp and the boot.

j. Covering. Refer to Chapter 3.9 Cover Soil Layer for additional information on cover soil placement.

(1) Pushing the cover soil across the geomembrane surface can cause large wrinkles to develop. Require the contractor to modify the placement procedure if the wrinkles become so large that they fold over and crease the geomembrane.

(2) Periodically inspect the surface of the geomembrane for bulges which may be an indication that gas or water is collecting beneath the geomembrane. Stop construction and notify the design district if this situation occurs.